

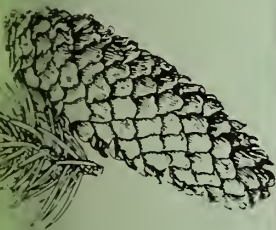
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A Southwestern Mixed Conifer Plantation— Case History and Observations

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Abstract

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Ponderosa pine, Douglas-fir, and two lots of blue spruce were planted on clearcuttings in east-central Arizona at about 9,200 ft elevation. The Douglas-fir and one lot of blue spruce were markedly inferior planting stock. After five growing seasons, survival and condition of the inferior planting stock were very poor. Many ponderosa pines were girdled during a meadow mouse outbreak, but on south slopes most of the survivors were vigorous. Survival and growth of blue spruce from good planting stock were good on north-facing slopes, but considerably poorer on south slopes. Management implications are discussed.

Keywords: *Pinus ponderosa*, *Picea pungens*, *Microtus*, planting.

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**A Southwestern Mixed Conifer Plantation—
Case History and Observations**

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¹Central headquarters maintained at Fort Collins, in cooperation with Colorado State University; research reported here was conducted at the Station's Research Work Unit at Flagstaff, in cooperation with Northern Arizona University.

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A Southwestern Mixed Conifer Plantation—
Case History and Observations [1, 2, 3],

John R. Jones

Very little forest planting was done on Southwestern mixed conifer sites prior to 1970. For years the selection method had been the basis of harvesting mixed conifer forests, and natural regeneration was relied upon. The infrequent destructive fires in mixed conifers commonly were followed by extensive aspen² suckering, or, on some habitats, by profuse growth of Gambel oak.

In the ponderosa pine climax zone, ponderosa pine had been planted on a rather small scale for years, with some notable successes but a preponderance of failures. It also had been planted occasionally on mixed conifer burns with their more favorable moisture regimes, but survival did not seem any better.

Many causes have been suggested for failures: the severe spring dry seasons; competition from grasses; frost heaving; predation by pocket gophers and meadow mice; browsing by cattle, sheep, deer, and elk; and handling and planting practices that are inadequate for Southwestern conditions (Jones 1967, 1974).

Interest in clearcutting in the Southwest to obtain increased water yields grew out of watershed research in North Carolina, Colorado, and the Sierra Ancha in Arizona. In 1958-59, seven blocks of mixed conifer forest were clearcut on the Burro Creek Watershed, Apache National Forest, Arizona, to examine silvicultural side effects of clearcutting to increase water yield. Two blocks were planted with ponderosa pine. First-year survival was 27 percent. The seedlings which survived were virtually eliminated over the next several years through browsing by the numerous deer and elk attracted to the clearcuttings (Jones 1967). Browsing also eliminated aspen suckers. Of the scattered pines which survived browsing, most were killed by debarking during the winter of 1966-67, when meadow mouse populations became very high.

Research foresters had enjoyed an encouraging degree of success in small-scale experimental plantings of ponderosa pine. They felt that the numerous natural factors mentioned above, although the immediate causes of

failures, could commonly be overcome if the necessary knowledge were put together and used. This attitude was shared by the Branch of Silviculture in the Southwestern Regional Office of the USDA Forest Service and by numerous foresters in the field.

To test and extend our knowledge for the mixed conifer zone, an experiment was planned and installed by Robert S. Embry.³ It was designed to compare performances of four species on north- and south-facing slopes, with and without protection from browsing by game and cattle. This Paper reports the results of that experiment.

Area and Methods

The study was installed at 9,200-9,300 feet elevation on small mixed conifer clearcuttings along the Blue Lookout Road, Apache National Forest, Arizona. The locale averages about 33 inches of precipitation per year, with about 30 percent of it as July and August rains. Three sites were selected on north-facing and three on south-facing slopes. Their soils were similar—gravelly silt loams and gravelly silty clay loams derived from basalt. Slopes varied from 12 to 22 percent. At the time of planting, the sites were largely bare of competing vegetation. At each site, three contiguous subplots were laid out. One subplot, selected at random, was fenced to exclude cattle, deer, and elk; another to exclude cattle only; and a third was left unfenced. Each subplot was subdivided into four quarters, to each of which a different species was assigned at random: Douglas-fir, ponderosa pine, blue spruce, and Engelmann spruce.

At this point, the purpose and design of the study were compromised in two ways:

1. Although it was not apparent at the time of planting, as the "Engelmann" spruce seedlings grew and took on more definitive characteristics, it became clear that they were actually blue spruce seedlings grown in the nursery from mis-identified seed. Therefore we do not have

²Scientific names of plants and animals mentioned are listed at the end of this report.

³Formerly Associate Silviculturist at the Station's Research Work Unit at Flagstaff; now Hydrologist, Idaho Panhandle National Forests, St. Maries, Idaho.

Engelmann spruce in the study at all. Instead, we have a comparison of two very different lots of blue spruce planting stock. That shipped as Engelmann spruce will subsequently be referred to as normal-stock blue spruce and the other as poor-stock blue spruce.

2. The quality of planting stock differed markedly by species, which confounds most species comparisons. The ponderosa pine, like the normal-stock blue spruce, was good. The Douglas-fir stock, 4 years in the seedbeds, had tall, spindly tops and long, sparsely branched root systems, but was the only Douglas-fir available from Southwestern sources. The poor-stock blue spruce were mostly only 2 to 3 inches tall, with densely branched root systems only 3 to 4 inches long.

Species selection reflected several considerations. All are significant mixed conifer species. Ponderosa pine and blue spruce seem well adapted to the full sunlight found on clearcuttings. The suitability of Engelmann spruce and Rocky Mountain Douglas-fir for regenerating clearcuttings was questionable (Jones 1974); this study was to provide a test. Observations also had suggested that the spruces were much less attractive to browsing game and cattle (Jones 1974) and less subject to girdling by mice. Ponderosa pine definitely seemed more resistant to drought, but it also seemed quite possible that, with competing grasses initially absent, spruce and Douglas-fir nursery stock would be able to survive dry seasons on south-slope clearcuttings.

A planting program did not yet exist on the Apache National Forest, so the planting stock used was from other Southwestern seed sources. Choices were very limited. Shipping invoices described the planting stock and seed sources as follows:

2-0 ponderosa pine, Sitgreaves National Forest, Arizona.

4-0 Douglas-fir, Carson National Forest, New Mexico.

3-0 blue spruce, Carson National Forest, New Mexico.

3-0 Engelmann spruce, Carson National Forest, New Mexico.

The first three lots were raised at the Lucky Peak Nursery, Boise, Idaho, and the fourth at the Mt. Sopris Nursery, Basalt, Colorado.

The sites were planted in the spring of 1970—the south slopes in mid-April when the seedlings arrived, and the north slopes at the end of April when the snow melted from them. An exception was the “Engelmann” spruce

planting stock, which was not received until early May.

The seedlings were planted in slits made with planting bars. The method was standard at that time, but is no longer recommended (Jones 1974, Ronco 1972, Schubert et al. 1969, 1970).

After the study plots had been planted, excess seedlings were planted in a small cattle enclosure where orchardgrass had been established earlier beside the logging road. There were 40 normal-stock blue spruce, 40 Douglas-fir, 38 ponderosa pine, and 32 poor-stock blue spruce in this accessory plot. These extra trees were planted in the thick orchardgrass without site preparation and watered weekly until the summer rains began in July. They were not formally part of the study.

During the first growing season, 1970, the seedlings were examined every 7 to 10 days. At appropriate intervals during the spring and summer of 1970, soil moisture was measured at depths of 0-4 and 4-8 inches on each study plot. In 1971 seedlings were checked three times, in 1972 twice, and in 1973 once. A closing examination was made in September 1974, when the height of each survivor was measured.

During the 1970 and 1971 examinations each live tree was rated as healthy or unhealthy. Beginning in 1972, live seedlings were classed as:

Good—healthy-looking seedlings growing well.

Hopeful—seedlings with a notable lack of vigor or, if vigorous with some other serious impairment, but considered to have a substantial chance to survive and grow.

Doubtful—seedlings judged unlikely to survive.

Criteria included: amount and condition of foliage; length of leader, both as an absolute and with respect to previous size; size of new buds; and physical damage such as gnawing, browsing, and breakage. Competitive situation, such as being overtopped by dense raspberry, was not a criterion; only characteristics of the seedling itself were used to rate condition.

Results

Except where otherwise specified, data are from the study proper, and do not include data from the accessory plot.

Soil Moisture

The dry season immediately following planting was normal. Soil water potential beneath the bare-plot surfaces did not reach -2 bars until late June, however, and then only on

some plots. At no time did it approach the permanent wilting point.⁴ Rains beginning early in July kept the soil near field capacity until sampling was discontinued in September.

Survival and Growth of Different Stocks

After five growing seasons, normal-stock blue spruce had survived best and had most trees rated good, followed by ponderosa pine, poor-stock blue spruce, and Douglas-fir (table 1). Heights tabulated are averages for trees rated good. The tallest of all was a very exceptional ponderosa pine which reached 66 inches.

Table 1.--Survival and growth of seedlings for five growing seasons on formal study plot and on an accessory plot

Plot data	Survival	Rated 'Good'	Height
	- Percent -		Inches
STUDY PLOT:			
Spruce, normal-stock	67	37	23.3
Ponderosa pine	26	19	26.5
Spruce, poor-stock	23	10	19.1
Douglas-fir	19	8	22.0
ACCESSORY PLOT:			
Spruce, normal-stock	93	55	14.8
Ponderosa pine	26	18	18.7
Spruce, poor-stock	6	0	--
Douglas-fir	5	0	--

On the accessory plot, planted in grass and watered through the first dry season, 5-year survival for ponderosa pine was almost exactly the same as in the study proper (table 1). Surprisingly, survival of the normal-stock blue spruce was much better on this plot than in the study proper. Almost all the Douglas-fir and the poor-stock blue spruce died the first year.

Initial growth on the accessory plot was relatively poor; the trees hardly grew at all until the fourth growing season, when a number of them showed considerably improved vigor. At the end of the fifth growing season, heights were relatively uniform; no tree was taller than 21 inches.

Causes of Death

Little can be said about the immediate causes of death of Douglas-fir and poor-stock

blue spruce, but the basic cause seems to have been their initial poor quality. Almost all showed poor vigor the first year, and most remained in poor condition until they died. Most of the survivors show little tendency toward recovery.

Ponderosa pine.—Rodents killed 34 percent of all the ponderosa pines planted in the study proper; 204 were girdled by meadow mice while pocket gophers girdled or cut the roots of 15. Eleven other pines were missing, and rodents are a plausible explanation. Virtually all the pocket gopher damage was in 1972 on two of the 18 plots. A large majority of the meadow mouse damage came during the winter of 1973-74, when populations were very high throughout the White Mountains. Many pines were stripped of bark from the ground to the terminal shoot, and smaller pines commonly were cut off. A number of the larger pine seedlings had only a narrow girdle of bark removed. Many surviving pines had been partly girdled, but in most such cases the subsequent (1974) growth seemed normal. A few had been girdled or even completely debarked above the lowest branch, leaving a live but small and deformed seedling.

A few plots had little rodent damage. The accessory plot had no trees killed by rodents, and only one damaged.

Other identified factors killed fewer than 4 percent. They include trampling (15 seedlings), burial by soil, rocks, or cow manure (five seedlings), and browsing (one seedling). In a very dense patch of raspberry the death of four seedlings was ascribed to competition.

No cause could be identified for 220 deaths (34 percent of the pines planted). Of these, 195 died during the first 2½ years and were very largely trees which showed poor vigor from the beginning; 63 pines died the first summer. Mortality was not associated more with one slope direction than with the other.

Blue spruce.—In contrast with ponderosa pine, only 3 percent of the normal-stock spruce, 20 trees, were killed by rodents. Other identified causes were trampling (six trees, less than 1 percent), competition (two trees), cow manure and a falling snag (one tree each). The other 183 that died (28 percent of those planted) succumbed to unidentified causes. Because 115 died during or just after the exceptional 1974 drought, 98 of them on southerly slopes, drought is clearly implied. These included numerous seedlings taller than 20 inches that previously had been rated good. Many of the blue spruce survivors classed as only hopeful or doubtful in 1974 had dropped most or all of their pre-1974

⁴Permanent wilting point is generally taken as -15 bars unless otherwise defined. Seedlings do not necessarily die when the soil water potential reaches or exceeds -15 bars.

needles during the drought; nearly all of these were on southerly slopes.

Effects of Fencing

Survival and condition class differences between fencing treatments were trivial and statistically insignificant. This is consistent with the scarcity of deaths assignable to cattle or game.

Seedling height differences between fencing treatments also are trivial, which is consistent with the infrequency of browsing or serious trampling damage on the unfenced plots.

Effects of Slope Direction

Pine survival was substantially greater on southerly slopes (33 percent) than on northerly slopes (20 percent, fig. 1), but the difference was statistically insignificant because of the large error variance. Of all pines planted on southerly slopes, 27 percent were rated good at the end of 1974; on northerly slopes the percentage was only 10. This difference was statistically significant ($P < 0.05$).

In contrast, survival of normal-stock spruce was much better on northerly slopes than on southerly: 80 percent compared to 53 percent, while those rated good were 59 and 16 percent, respectively, of all planted. These dif-

ferences were highly significant ($P < 0.01$). The differences on different aspects were even greater for Douglas-fir and poor-stock blue spruce.

Effect of slope direction on height was not analyzed statistically. For trees rated good the differences were trivial on the different slope aspects. For all surviving trees, height differences simply reflect differences in the proportions of trees of good vigor.

Discussion

One lesson learned from this study is already well known in regions with established major planting programs: successful planting is only the first step toward a satisfactory new forest. The plantations must then be monitored for subsequent hazards, the relative importance of which varies from region to region and, to some extent, from habitat to habitat within a region. This study, as well as recent research in the ponderosa pine climax zone and operational experience, points to the particular importance of monitoring rodent populations and the conditions which influence outbreak populations. Development of severe shrub competition can also become a problem on some sites. Although not a problem in this study, damage from browsing, trampling, and perhaps insects may require attention.

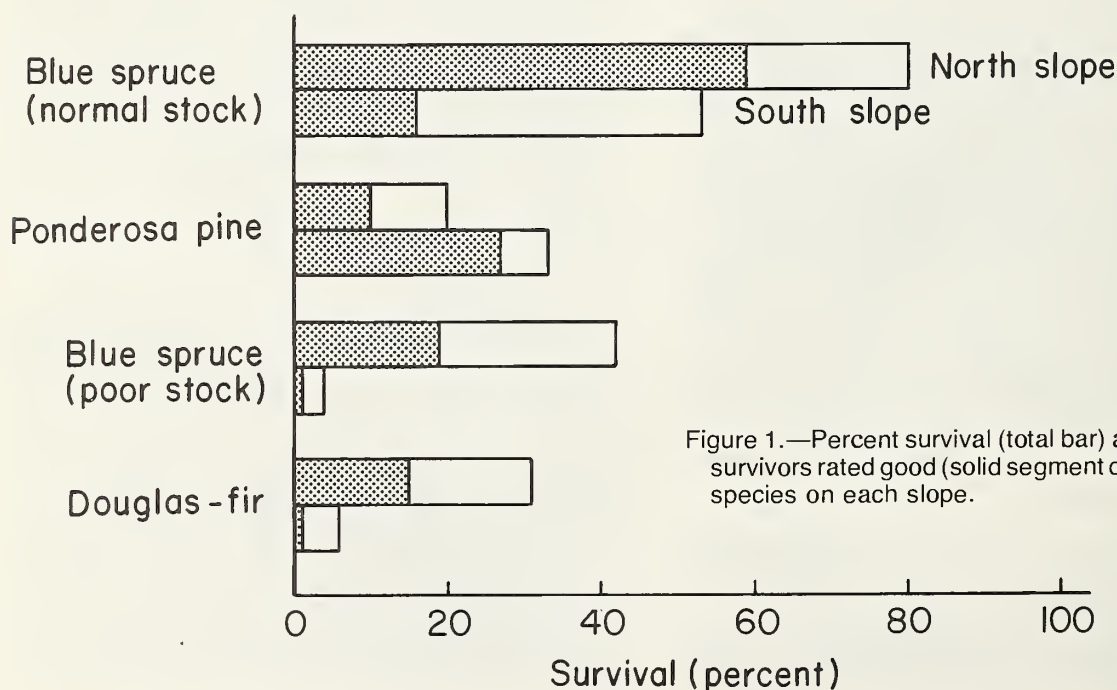


Figure 1.—Percent survival (total bar) and percent of survivors rated good (solid segment of bar) for each species on each slope.

Another lesson has been the importance of slope direction and its relation to species selection. Near winter's end, the snowpack on even a moderate north-facing slope is considerably deeper than on a similar south-facing slope, as indicated in figures 2 and 3 by the amount of 8-foot elk fence exposed. Commonly, snowmelt exposes seedlings to the sun and air 3 to 4 weeks earlier on open south slopes. This exposure often occurs after the beginning of the spring drought, which is characterized by mostly clear skies and persistent winds, with midday relative humidities frequently about 10 percent.

At mixed conifer elevations, soil moisture stresses under bare-soil surfaces are probably seldom severe below the upper 2 inches or so, even on south slopes. Where grass is well established, however, soil moisture stresses in June become severe on southerly slopes and level ground to a depth of at least 16 inches (Embry 1971).

In natural regeneration with root systems as large as those of normal planting stock, tissue moisture stresses are unlikely to become high during the dry season if competition is not serious (Embry 1971; Jones 1971, 1972). In newly planted seedlings, however, lethal moisture stresses may develop during the dry season even where considerable soil moisture is available, presumably because the transplanted root system is not yet functioning adequately to cope with severe atmospheric moisture stresses.⁵

Substantial amounts of grass, weeds, bracken, shrubs, or aspen developed on most plots after planting, but until the abnormally severe drought of the spring and early summer of 1974, almost all the normal-stock spruce still were alive and growing well. Yet spruce on south slopes suffered heavy mortality in 1974, and many survivors lost much of their foliage, presumably due to drought intensified by competition. This was not simply attrition of the weaklings—many of the spruce on southerly slopes that died in 1974 had been large and vigorous the previous autumn.

On the other hand, fewer ponderosa pines died on the warm southerly slopes, and the proportion of trees rated good there was much higher than on northerly slopes. The logical factors seem to be the persistent snow cover, cool microclimates, and cool soils on high-elevation northerly slopes. The elevation of the seed source, 1,800 feet lower than the planting site, may have been an important contributing factor. Performance on the north slope might have

⁵Unpublished research on ponderosa pine and Engelmann spruce. Rocky Mt. For. and Range Exp. Stn. Provided by W.J. Rietveld, Flagstaff, Arizona, and Frank Ronco, Fort Collins, Colorado, respectively.



Figure 2.—Three- to four-foot snowpack on 17-percent slope facing S5°E. March 2, 1973.



Figure 3.—Five- to six-foot snowpack on 22-percent slope facing N5°E. March 2, 1973.

been substantially better, had seedlings from a high-elevation source been available.

Although an afterthought, and not formally part of the study, the watered plot in thick orchardgrass proved interesting. Orchardgrass reduces soil moisture to critical levels during the dry season—it was the major grass on Embry's (1971) benchmark soil-moisture study—and has been associated with plantation failures in the past. On this plot a disproportionate number of pines died the first year despite watering, and while 5-year survival almost exactly equaled the study average for pine, none of the deaths on the accessory plot were attributable to rodents. Almost all of the normal-stock spruce, on the other hand, survived

through the five summers, and there was no indication of drought injury during 1974. The ambiguities, absence of an unwatered treatment in orchardgrass, and the lack of replication make interpretation difficult. Heavy first-year mortality suggests that orchardgrass has important effects on ponderosa pine beyond reduction of soil moisture. Excellent survival of blue spruce with first-year watering suggests that high soil-moisture stresses are much less critical after the first year.

Unfortunately, watering is totally impractical on an operational scale. Site preparation is practical but expensive. Cheapest, of course, is to not seed grass at all, and reforest promptly before competition necessitates site preparation. Even where important soil losses are a genuine threat, seeding a quick-starting rainy season annual such as black mustard is an alternative that should be much more compatible with reforestation. The mustards provide excellent living soil protection the first summer and dead mulch the second (Lavin and Springfield 1955, p. 38).

Severe woody competition was uncommon on the study plots. Ponderosa pine was badly suppressed by levels of shrub competition that did not seriously retard blue spruce growth. A dense raspberry patch (fig.4), which was not there at the time of planting, has seriously suppressed the few Douglas-firs surviving beneath it. Dense raspberry with an overstory of locust saplings also developed on a north-slope normal-stock spruce plot (fig. 5). While 26 of the 36 spruce in this thicket were still alive at the end of the study, only two were rated good. Where competition was primarily from weedy forbs, seedlings were in much better condition (fig. 6).

Use of the habitat type classification being developed by the Southwestern Region of the USDA Forest Service should assist preplanting evaluation of probable shrub competition.

Competition from aspen suckers had not yet retarded the growth of either spruce or pine. Aspen regeneration was not heavy on any of the plots, however, amounting at the most to individuals and small clumps that had not formed a



Figure 4.—Dense raspberry
on a Douglas-fir plot.



Figure 5.—Dense raspberry
and locust on a blue
spruce plot.

closed canopy. On some clearcuttings, including some unplanted parts of those in this study, suckering has been heavy. The resulting dense stands of aspen saplings would provide critical competition for ponderosa pine seedlings, and would no doubt retard the growth of other conifers significantly.



Figure 6.—Vigorous spruce on northerly slope. Stalks of competing forbs were removed to show the spruce more clearly.

Rodents generally have been considered an important problem in ponderosa pine plantations in the Southwest (Schubert 1974). Also, observations following the major meadow mouse outbreak in the winter of 1966-67 indicated that meadow mice prefer Douglas-fir to Engelmann spruce. This study found meadow mice strongly favoring ponderosa pine over blue spruce, and suggested the same order of preference by pocket gophers.

In the White Mountains the last two major meadow mouse outbreaks were 7 years apart. Damage was severe to natural regeneration as well as to plantations. In the intervening years mouse damage was significant only in places. It is not known how typical that 7-year interval is.

The 66-inch-tall pine in figure 7 completely was surrounded by smaller pines killed by mice. The larger tree tentatively had been gnawed at several points, but at no point did the attacks penetrate the inner bark. It is interest-

ing to consider the possibility that, when they become taller than 50 or 60 inches, ponderosa pines become unattractive to meadow mice. In this study, however, several pines taller than 40 inches partly or entirely were girdled.

Grass seeding on these clearcuts was limited almost entirely to roads and roadsides, and use by cattle was concentrated largely on the seeded areas. Rather light general use of the clearcuts by cattle did only scattered minor damage.

The high deer and elk populations of the late 1950's and early 1960's seriously damaged regeneration of most coniferous species, but not the spruces, in numerous Arizona locales (Heidmann 1963; Jones 1967, 1974; Schubert 1974). The existing relatively light populations did no apparent damage on this study area, however.

Management Conclusions

- Plantations should be systematically examined to monitor rodent populations, competition, and other potentially damaging agents.



Figure 7.—

Vigorous 66-inch pine
surrounded by pines
killed by meadow mice.

- Poor-quality planting stock should not be shipped. If received it should not be planted.
- On southerly slopes, vigorous blue spruce seedlings taller than 20 inches may still be killed in years of severe drought.
- Until more specific guidelines are available, a conservative working guide might be: (a) do not plant ponderosa pine on northerly slopes 500 feet higher than the seed source, and (b) do not plant ponderosa pine on northerly slopes at all above about 8,500 feet unless the seed source is from an elevation at least as high.
- Ponderosa pine seems preferable to blue spruce for planting in the open on southerly slopes, provided that: (a) rodent populations and competition from shrubs or aspen are controlled where necessary, and (b) heavy use of the area by cattle, deer, or elk is not expected.

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Common and Scientific Names of Plants and Animals Mentioned

Aspen (quaking)	<i>Populus tremuloides</i> Michx.
Black mustard	<i>Brassica nigra</i> (L.) Koch
Blue spruce	<i>Picea pungens</i> Engelm.
Bracken	<i>Pteridium aquilinum</i> (L.) Kuhn
Deer (mule)	<i>Odocoileus hemionus hemionus</i> Rafinesque
Douglas-fir (Rocky Mountain)	<i>Pseudotsuga menziesii</i> var. <i>glauca</i> (Beissn.) Franco
Elk	<i>Cervus canadensis nelsoni</i> Bailey
Engelmann spruce	<i>Picea engelmannii</i> Parry
Gambel oak	<i>Quercus gambellii</i> Nutt.
Locust (New Mexico)	<i>Robinia neo-mexicana</i> A. Gray
Meadow mouse	<i>Microtus</i> spp.
Orchardgrass	<i>Dactylis glomerata</i> L.
Pocket gopher (Botta's)	<i>Thomomys bottae</i> Eydoux & Gervais
Ponderosa pine	<i>Pinus ponderosa</i> Laws.
Raspberry	<i>Rubus strigosus</i> Michx.

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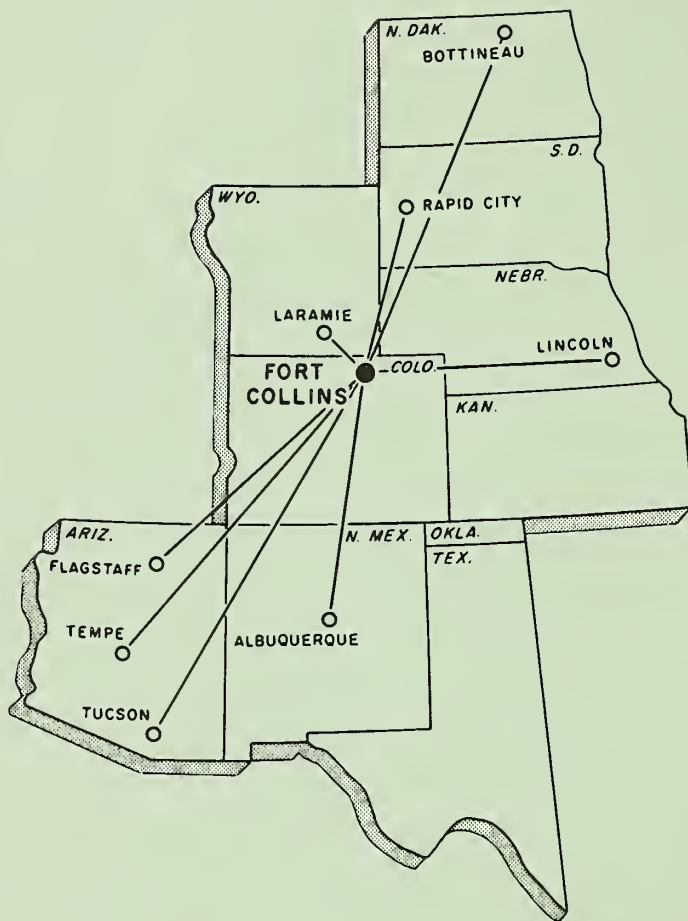
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Ponderosa pine, Douglas-fir, and two lots of blue spruce were planted on clearcuttings in east-central Arizona at about 9,200 ft elevation. The Douglas-fir and one lot of blue spruce were markedly inferior planting stock. After five growing seasons, survival and condition of the inferior planting stock were very poor. Many ponderosa pines were girdled during a meadow mouse outbreak, but on south slopes most of the survivors were vigorous. Survival and growth of blue spruce from good planting stock were good on north-facing slopes, but considerably poorer on south slopes. Management implications are discussed.

Keywords: *Pinus ponderosa*, *Picea pungens*, *Microtus*, planting.





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